

Short GRB Prompt and Afterglow Correlations

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Abstract

The *Swift* data set on short GRBs has now grown large enough to study correlations of key parameters. The goal is to compare long and short bursts to better understand similarities and differences in the burst origins. In this study we consider the both prompt and afterglow fluxes. It is found that the optical, X-ray and gamma-ray emissions are linearly correlated - stronger bursts tend to have brighter afterglows, and bursts with brighter X-ray afterglow tend to have brighter optical afterglow. Both the prompt and afterglow fluxes are, on average, lower for short bursts than for long. Although there are short GRBs with undetected optical emission, there is no evidence for “dark” short bursts with anomalously low opt/X ratios. The weakest short bursts have a low X-ray/gamma-ray ratio.

Key words: gamma-ray bursts

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1 *Swift* SHORT GRB OBSERVATIONS

The *Swift* mission (Gehrels et al. , 2004) has detected and slewed to 19 short bursts. Afterglows in X-ray, optical, and radio have been detected. Host galaxies and redshifts have been found in some cases. Having such information is a major breakthrough following years of little knowledge about short bursts. However, the short bursts are still difficult to observe as they tend to have weaker fluences and afterglows than long bursts. For example, for the *Swift* 19 short bursts 74% are detected in X-rays and 26% in optical, compared to 98% X-ray and 58% optical for long bursts. (*Swift* slewed promptly to all of the 19 short bursts, so the comparison is made to long bursts with prompt slews.)

For redshifts, the comparison is more favorable. There are 4 firm redshifts out of 19 bursts or 21% compared to 57 out of 225 or 25% for *Swift* long GRBs. A

Optical (R-band) Flux vs. X-ray (1 keV) Flux

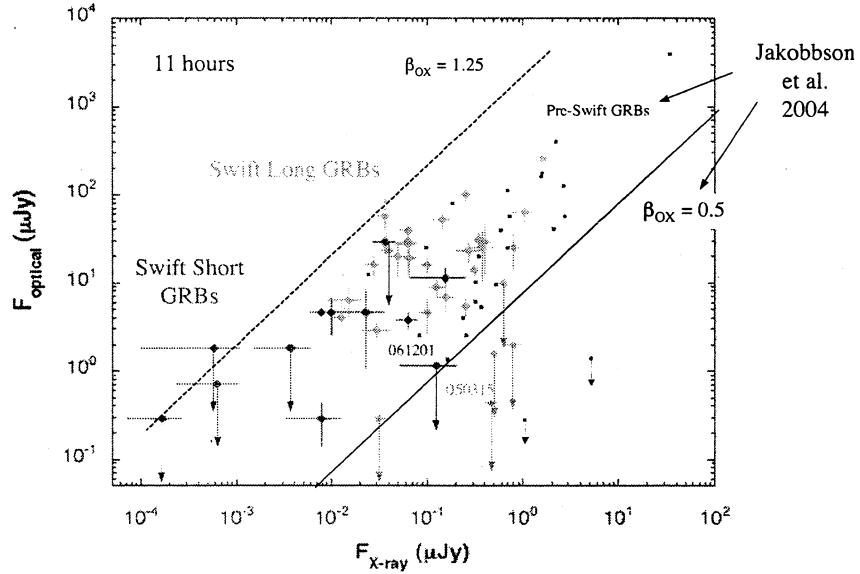


Fig. 1. The X-ray and optical fluxes of *Swift* short and long GRBs at 11 hours after the burst. Comparison is made to pre-*Swift* GRBs and to lines of optical to X-ray spectral index from Jakobsson et al. (2004). The gray points are *Swift* long bursts, the black points are *Swift* short bursts and the small black points without error bars are the pre-*Swift* GRBs.

considerable extra effort is made by ground-based observers to find redshifts for short bursts with good results. In fact, there are another 4 short bursts with redshift guesses from probable host galaxy associations. Interestingly, all of the short burst redshifts are from host galaxy spectroscopy. We have yet to determine a redshift directly from absorption lines in the afterglow. This is in contrast with long GRBs where 70% of the *Swift* redshifts are from absorption line spectroscopy of the afterglow emission.

We now turn attention to a quantitative comparison of the prompt and afterglow fluxes from short and long GRBs.

2 COMPARISON OF AFTERGLOW FLUXES

We use the methods developed by Jakobsson et al. (2004) to compare *Swift* X-ray and optical afterglow fluxes. In particular, we compare the X-ray flux at 1 keV to the R-band optical flux, both measured at 11 hours after the burst as shown in Figure 1. Jakobsson et al. (2004) proposed that true "dark" bursts are those that have low optical to X-ray ratio and defined those that fall below the line of optical to X-ray spectral index, β_{OX} , of 0.5 to be "dark".

Results from Figure 1 are as follows:

- 1) There is a linear correlation of optical and X-ray fluxes for both *Swift* long and shorts GRBs, but with significant spread.
- 2) The long *Swift* GRBs fall in the same general region of the plot as the pre-*Swift* long bursts, with some tend toward weaker average fluxes for the *Swift* events.
- 3) There are *Swift* long bursts that fall below the $\beta_{OX} = 0.5$ line and are "dark" as there were pre-*Swift* dark long bursts. GRB 050315 is an example of a *Swift* burst with particularly low opt/X-ray ratio.
- 4) The *Swift* short bursts fall on the same general correlation line as the long burst. The bright short GRB points are in the midst of the long GRB points, but in the lower regions.
- 5) The *Swift* short bursts have weaker afterglow fluxes on average than the long bursts. There are short burst points far below the lowest long burst points. The sample size is too small to determine at this time if the short bursts are a single population or if there is a group of faint short bursts and a separate group of bright short bursts.
- 6) To date there are no "dark" short bursts detected. There are several with no optical emission, but those tend to be the ones also with weak X-ray fluxes. There are no short-burst points that fall below the $\beta_{OX} = 0.5$ line.

3 COMPARISON OF PROMPT AND AFTERGLOW FLUXES

Figure 2 shows the correlation of *Swift* X-ray afterglow and gamma-ray prompt emissions for long and short GRBs. In particular, we compare the X-ray flux at 1 keV at 11 hours to the prompt gamma-ray fluence in the 15 - 150 keV band.

Results from Figure 2 are as follows:

- 1) There is a linear correlation of X-ray flux to gamma-ray fluence for the *Swift* long GRBs, but with a significant spread.
- 2) The bright *Swift* short burst points are in the midst of the long burst points, but in the lower regions.

X-ray (1 keV) Flux vs. γ -ray (15-150) keV Fluence

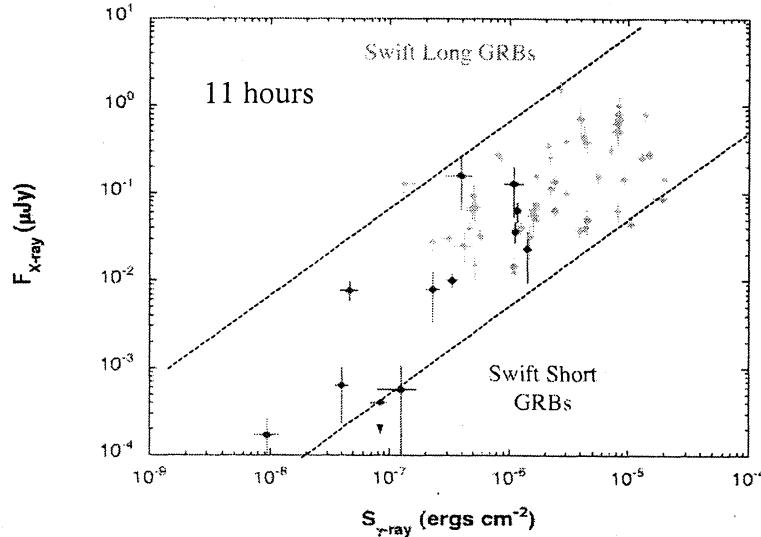


Fig. 2. The X-ray flux and gamma-ray fluence of *Swift* short and long GRBs at 11 hours after the burst. The gray points are *Swift* long bursts, the black points are *Swift* short bursts. The dashed lines are linear correlation lines that bound the populations.

3) The faint short bursts have lower X-ray to gamma-ray ratios than the average long bursts. This effect was noticed by Berger (2007) who called out the faintest 20% of short bursts as outliers in their X-ray to gamma-ray ratios. We confirm the conclusion that the faint short bursts have lower ratios, but note that their ratios do not fall outside the linear correlation line of the faintest long GRBs.

References

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